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Liu et al.

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(54) **SYSTEM AND METHOD OF DELIVERING VIDEO CONTENT**

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H04N 21/436	(2011.01)
H04N 21/6373	(2011.01)
H04L 29/06	(2006.01)

(52) **U.S. Cl.**

CPC ***H04N 21/472*** (2013.01); ***H04L 65/4076*** (2013.01); ***H04L 65/4092*** (2013.01); ***H04L 65/80*** (2013.01); ***H04N 21/438*** (2013.01); ***H04N 21/43615*** (2013.01); ***H04N 21/6373*** (2013.01)

(58) **Field of Classification Search**

CPC H04N 21/43615; H04N 21/438; H04N 21/472; H04N 21/6373

See application file for complete search history.

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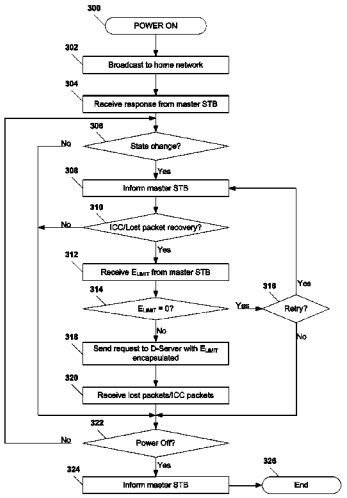
(57) **ABSTRACT**

A method includes receiving, at a server, a retry request from a media device. The retry request requests a data packet associated with video content and includes an overhead bandwidth factor corresponding to a ratio between an overhead bandwidth to be used to send the data packet in response to the retry request and a nominal bandwidth used to send video content to the media device. The method further includes, in response to the retry request, sending the data packet to the media device based on the overhead bandwidth factor.

20 Claims, 10 Drawing Sheets



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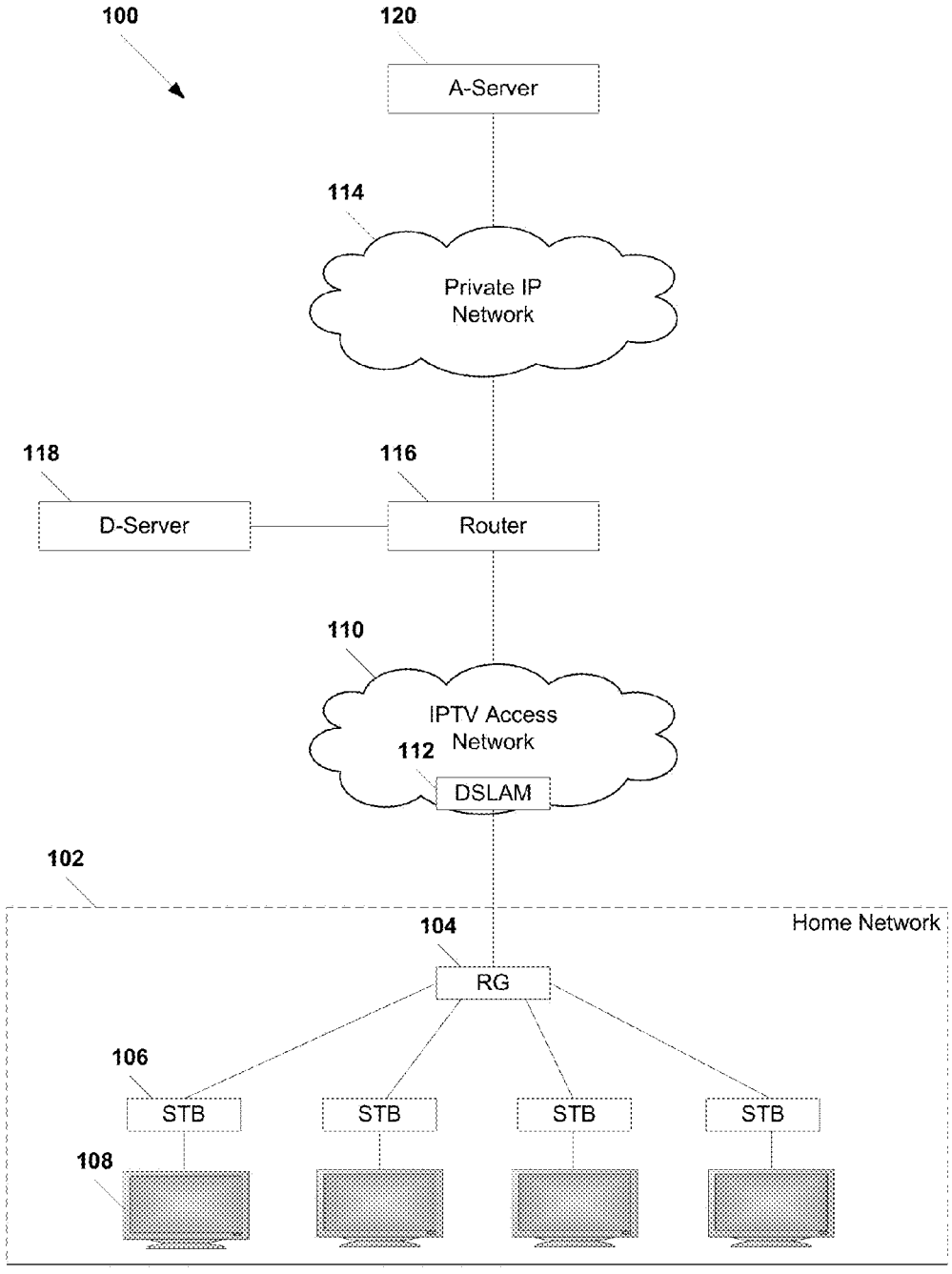
100
120
A-Server
114
Private IP Network
118
116
D-Server
Router
110
IPTV Access Network
112
DSLAM
102
Home Network
104
RG
106
STB
STB
STB
STB
108

FIG. 1A

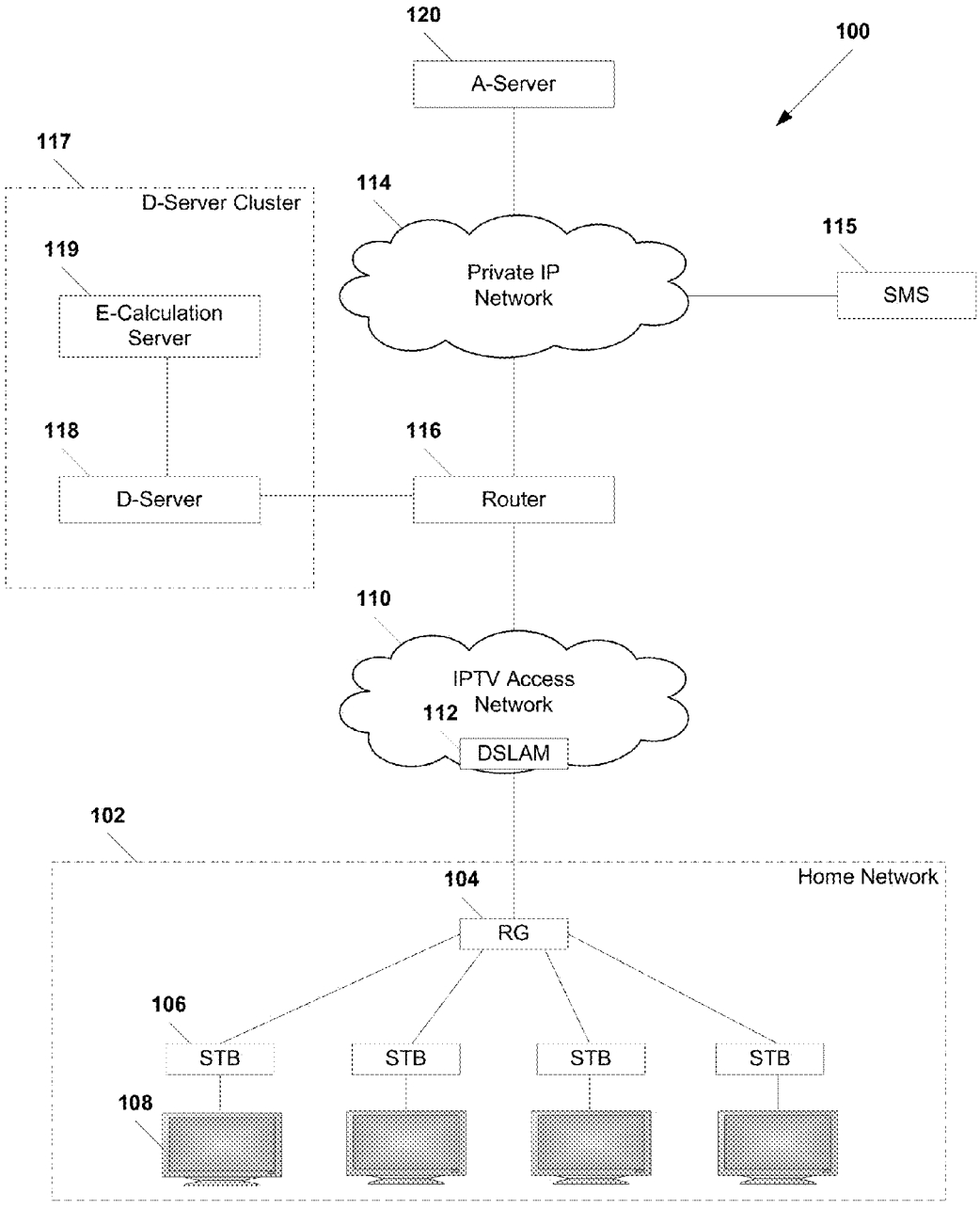
120
A-Server
100
117
D-Server Cluster
114
Private IP Network
115
SMS
119
E-Calculation Server
118
D-Server
116
Router
110
IPTV Access Network
112
DSLAM
102
Home Network
104
RG
106
STB
STB
STB
STB
108

FIG. 1B

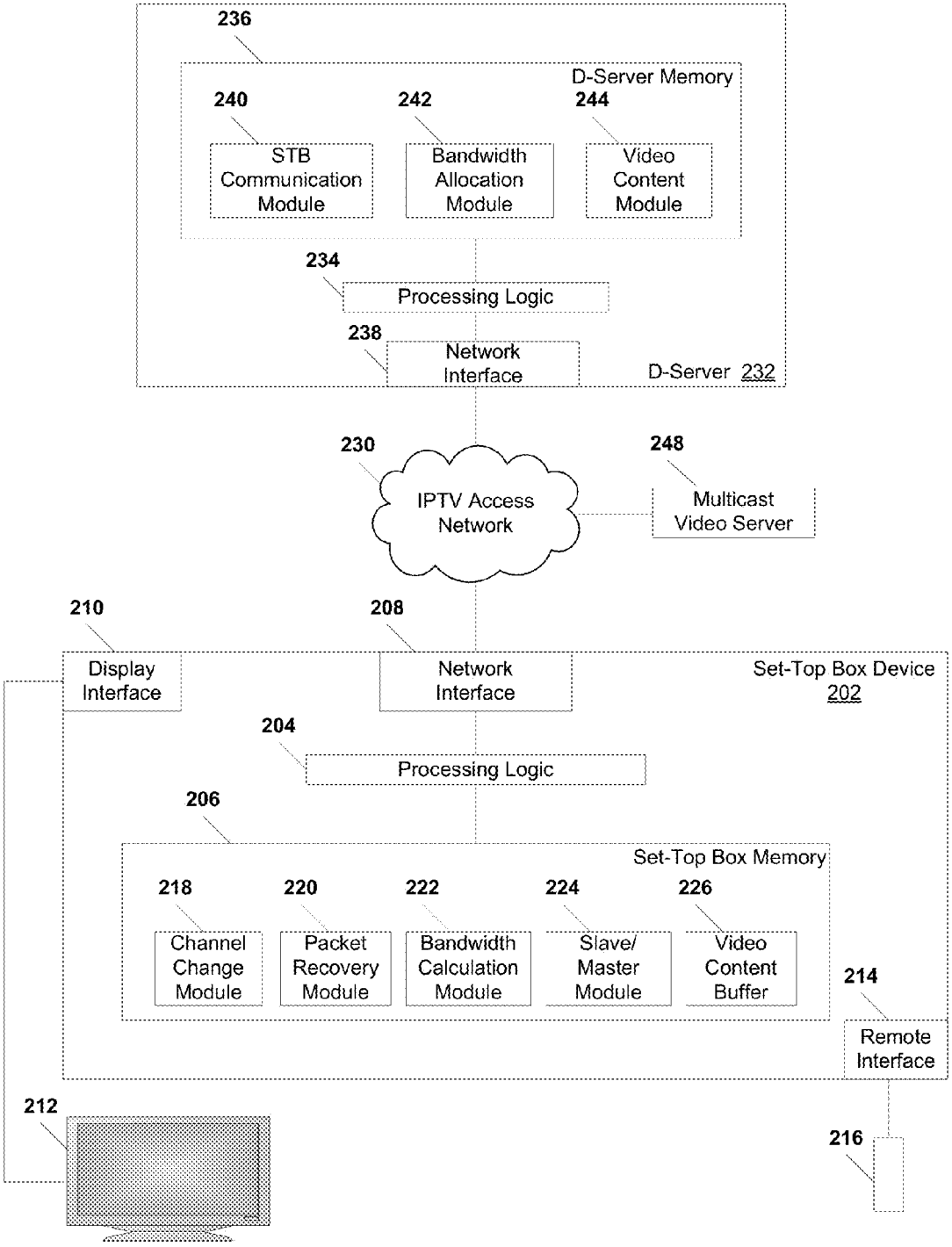
236
D-Server Memory
240
242
244
STB Communication Module
Bandwidth Allocation Module
Video Content Module
234
Processing Logic
238
Network Interface
D-Server 232
230
IPTV Access Network
248
Multicast Video Server
210
208
Display Interface
Network Interface
Set-Top Box Device 202
204
Processing Logic
206
Set-Top Box Memory
218
220
222
224
226
Channel Change Module
Packet Recovery Module
Bandwidth Calculation Module
Slave/ Master Module
Video Content Buffer
214
Remote Interface
212
216

FIG. 2

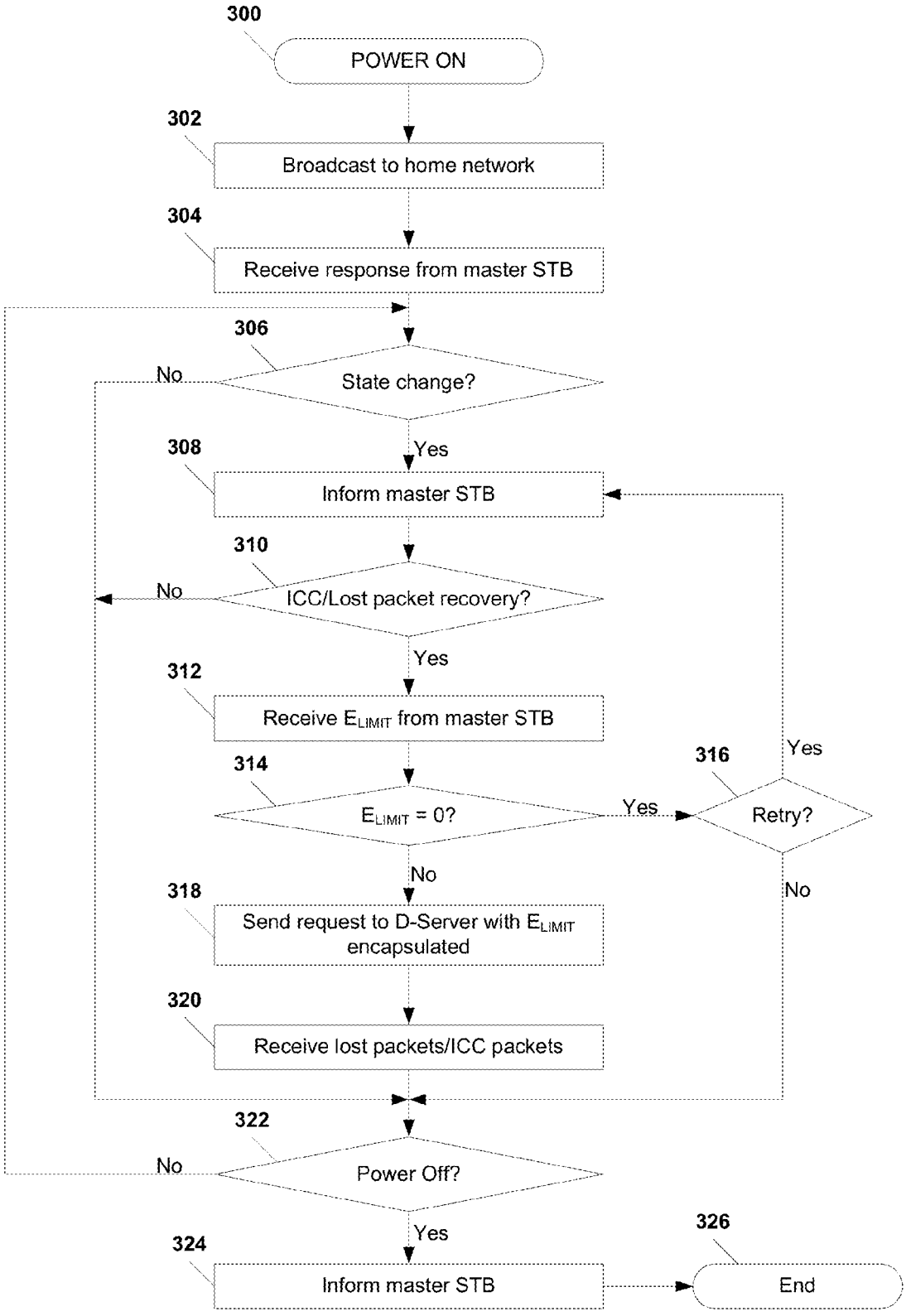
300
POWER ON
302
Broadcast to home network
304
Receive response from master STB
306
State change?
No
Yes
308
Inform master STB
310
ICC/Lost packet recovery?
No
Yes
312
Receive E_{LIMIT} from master STB
314
E_{LIMIT} = 0?
Yes
316
Retry?
Yes
No
No
318
Send request to D-Server with E_{LIMIT} encapsulated
320
Receive lost packets/ICC packets
322
Power Off?
No
Yes
324
Inform master STB
326
End

FIG. 3

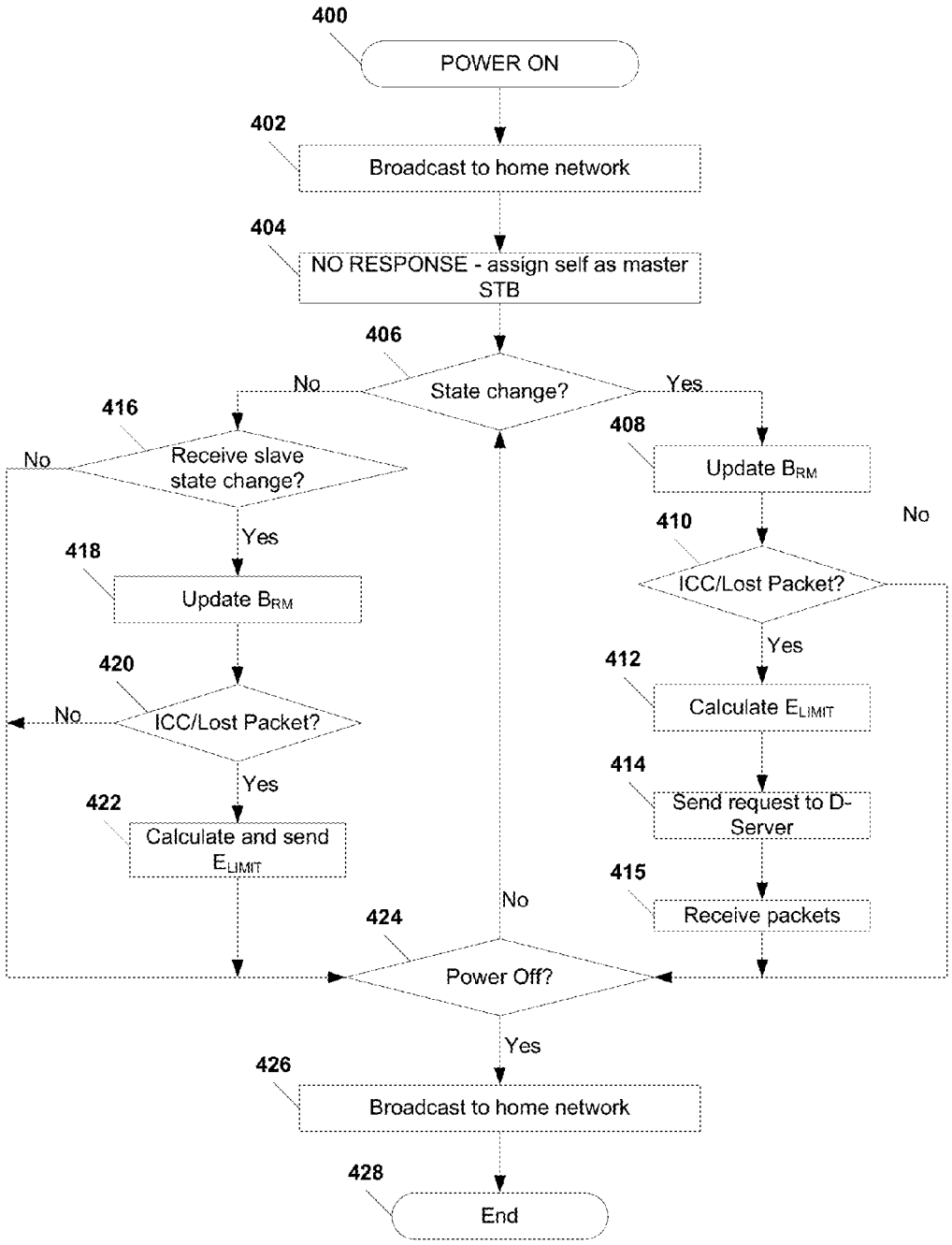
400
POWER ON
402
Broadcast to home network
404
NO RESPONSE - assign self as master STB
406
State change?
No
Yes
416
Receive slave state change?
No
Yes
418
Update B_{RM}
420
ICC/Lost Packet?
No
Yes
422
Calculate and send E_{LIMIT}
408
Update B_{RM}
410
ICC/Lost Packet?
No
Yes
412
Calculate E_{LIMIT}
414
Send request to D-Server
415
Receive packets
424
Power Off?
No
Yes
426
Broadcast to home network
428
End

FIG. 4

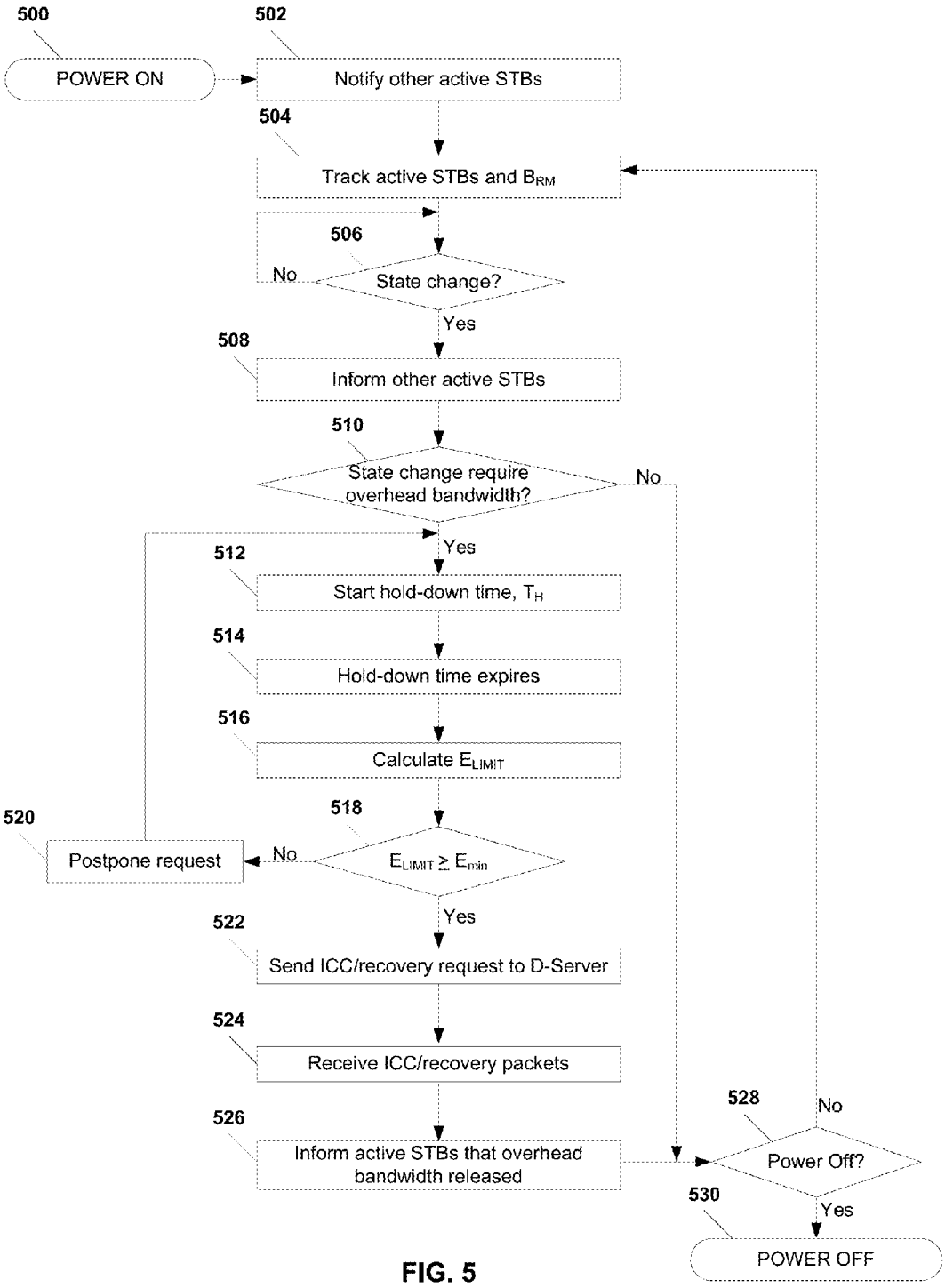
500
POWER ON
502
Notify other active STBs
504
Track active STBs and B_{RM}
506
State change?
No
Yes
508
Inform other active STBs
510
State change require overhead bandwidth?
No
Yes
512
Start hold-down time, T_H
514
Hold-down time expires
516
Calculate E_{LIMIT}
518
$E_{LIMIT} \geq E_{min}$
No
520
Postpone request
Yes
522
Send ICC/recovery request to D-Server
524
Receive ICC/recovery packets
526
Inform active STBs that overhead bandwidth released
528
Power Off?
No
Yes
530
POWER OFF

FIG. 5

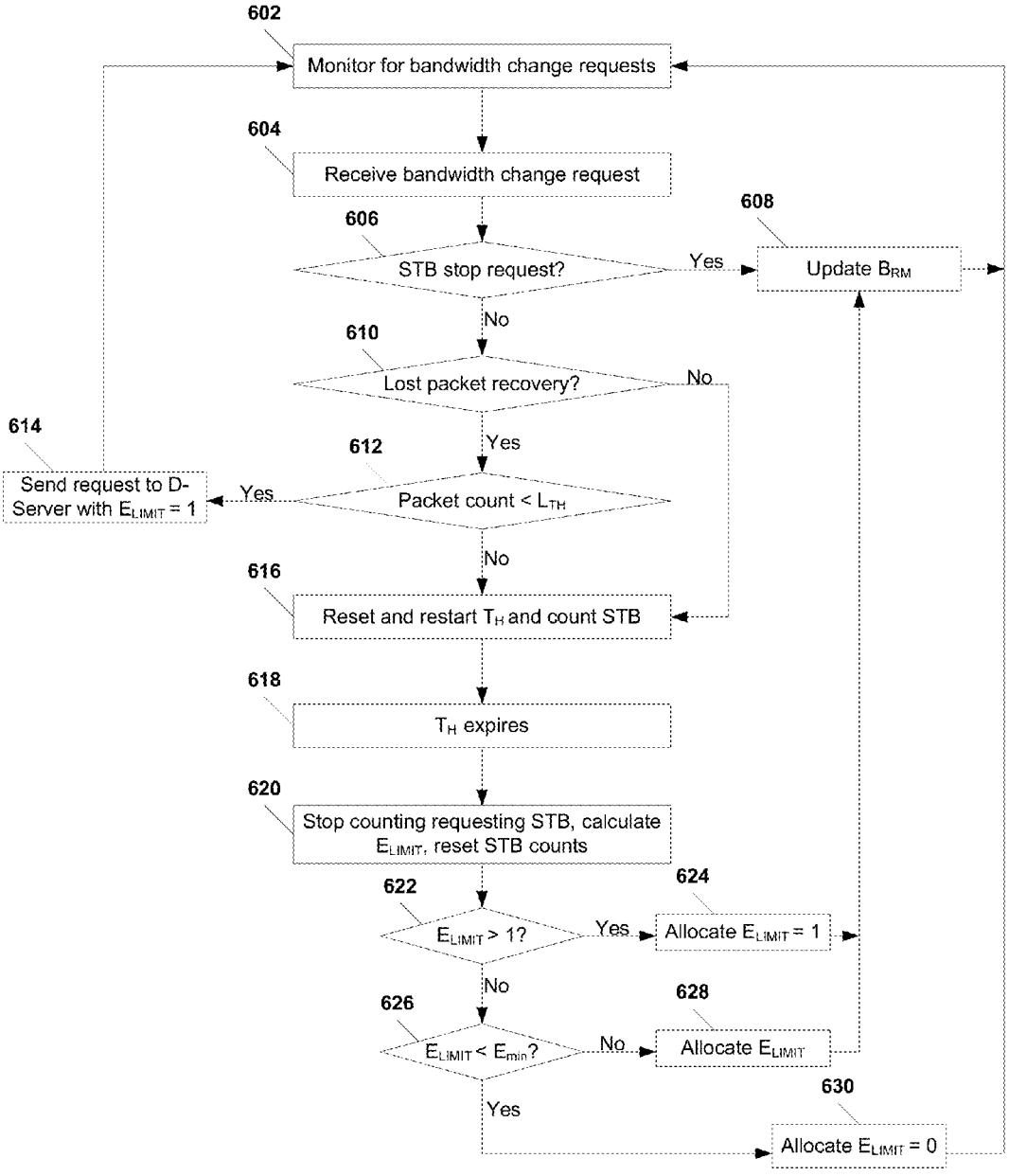
602
Monitor for bandwidth change requests
604
Receive bandwidth change request
606
STB stop request?
Yes
608
Update B_{RM}
No
610
Lost packet recovery?
No
Yes
614
Send request to D-Server with $E_{LIMIT} = 1$
Yes
612
Packet count < L_{TH}
No
616
Reset and restart T_H and count STB
618
T_H expires
620
Stop counting requesting STB, calculate E_{LIMIT}, reset STB counts
622
$E_{LIMIT} > 1$?
Yes
624
Allocate $E_{LIMIT} = 1$
No
626
$E_{LIMIT} < E_{min}$?
No
628
Allocate E_{LIMIT}
Yes
630
Allocate $E_{LIMIT} = 0$

FIG. 6

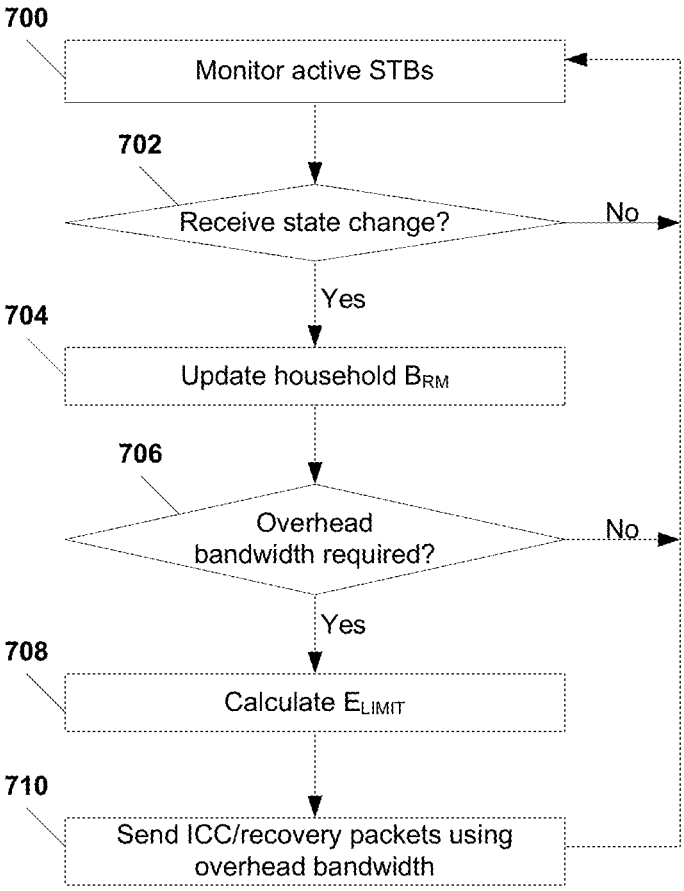
700
Monitor active STBs
702
Receive state change?
No
Yes
704
Update household B_{RM}
706
Overhead bandwidth required?
No
Yes
708
Calculate E_{LIMIT}
710
Send ICC/recovery packets using overhead bandwidth

FIG. 7

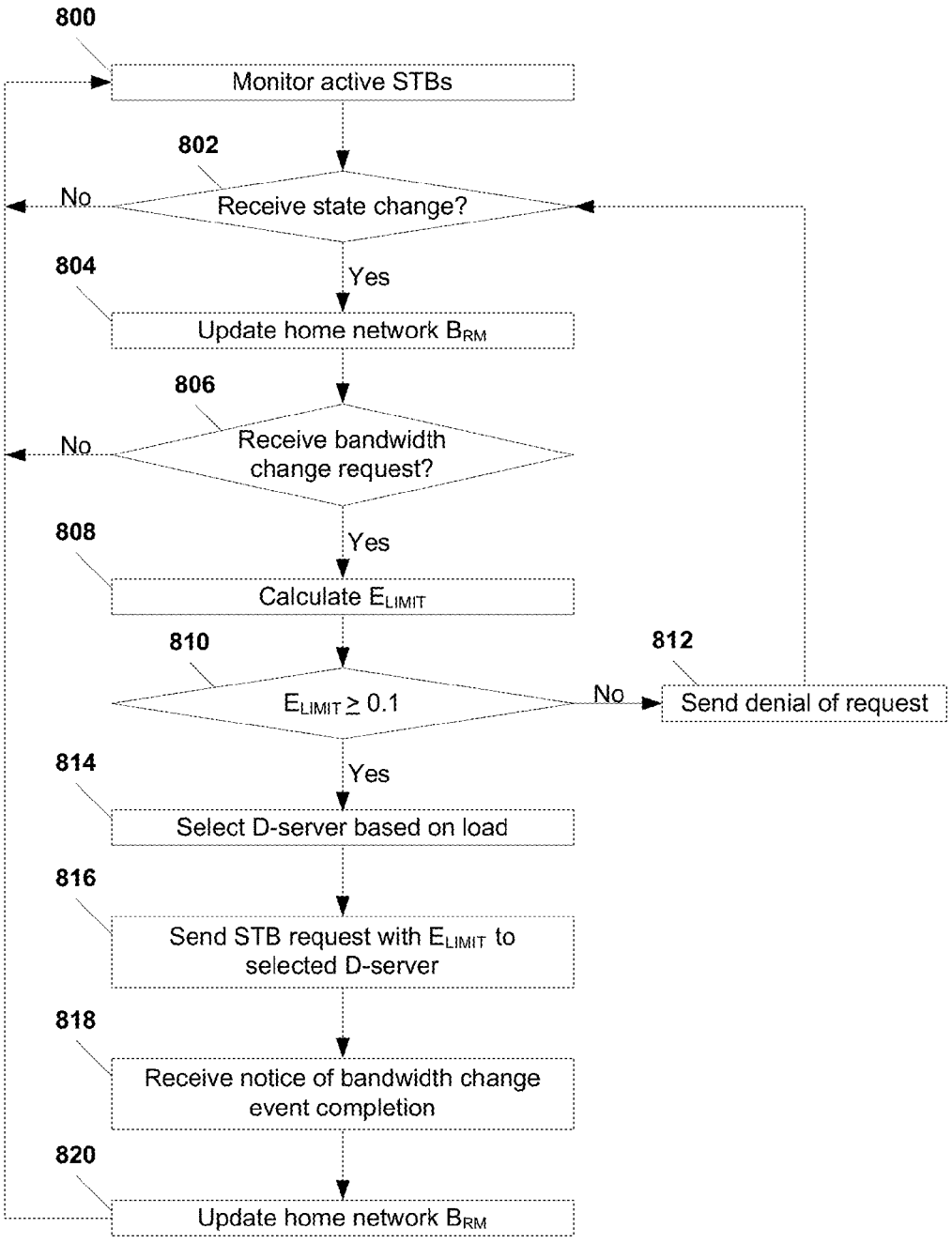
800
Monitor active STBs
802
Receive state change?
No
Yes
804
Update home network B_{RM}
806
Receive bandwidth change request?
No
Yes
808
Calculate E_{LIMIT}
810
$E_{LIMIT} \geq 0.1$
No
812
Send denial of request
Yes
814
Select D-server based on load
816
Send STB request with E_{LIMIT} to selected D-server
818
Receive notice of bandwidth change event completion
820
Update home network B_{RM}

FIG. 8

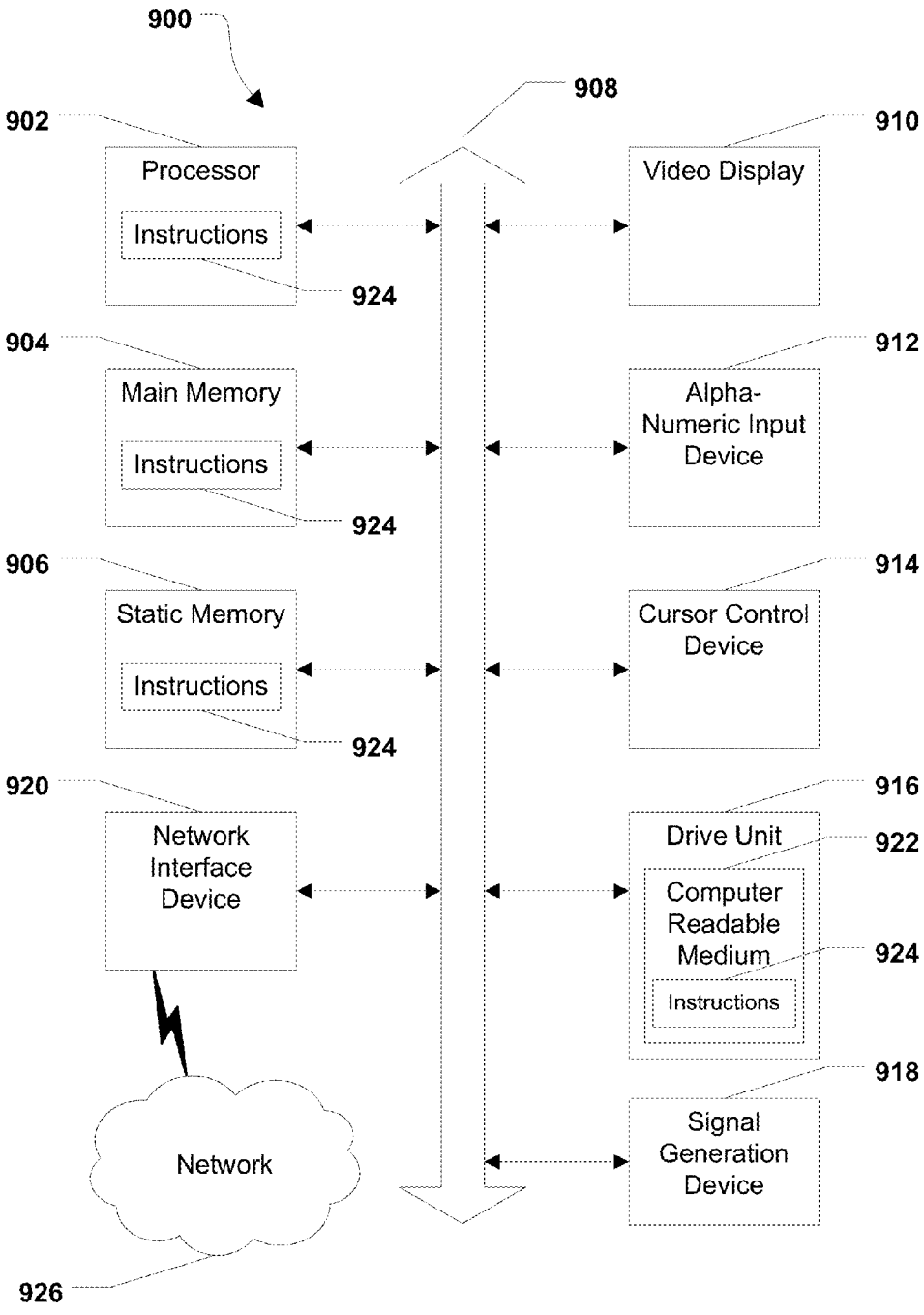
900
908
902
910
Processor
Instructions
924
Video Display
904
912
Main Memory
Instructions
924
Alpha-Numeric Input Device
906
914
Static Memory
Instructions
924
Cursor Control Device
920
916
Network Interface Device
Drive Unit
922
Computer Readable Medium
924
Instructions
918
Network
Signal Generation Device
926

FIG. 9

SYSTEM AND METHOD OF DELIVERING VIDEO CONTENT

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from and is a continuation application of U.S. patent application Ser. No. 13/477,163, filed on May 22, 2012, and entitled "SYSTEM AND METHOD OF DELIVERING VIDEO CONTENT," which claims priority from and is a continuation of U.S. application Ser. No. 11/848,818, filed Aug. 31, 2007, now U.S. Pat. No. 8,209,728, and entitled "SYSTEM AND METHOD OF DELIVERING VIDEO CONTENT," each of which is expressly incorporated herein by reference in its entirety.

FIELD OF THE DISCLOSURE

The present disclosure is generally related to delivering video content.

BACKGROUND

Using an IP network to provide video services in addition to voice and data services can present quality of service challenges. For instance, the bandwidth allotted to a single household communicating with an IP network can be limited by loop length, loop condition, or other physical layer constraints. If the overall IP traffic streamed to the household exceeds the allotted bandwidth, other traffic may be dropped, causing other households to experience service degradation. This can be particularly true with respect to video traffic, the quality of which can be especially sensitive to packet loss. Nonetheless, certain events, such as channel change and lost packet recovery may require additional bandwidth to meet quality of service standards for video traffic, while still avoiding bandwidth overflow. Accordingly, there is a need for an improved system and method of delivering video content.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a block diagram of a particular embodiment of a system to deliver video content;

FIG. **1**B is a block diagram of a second particular embodiment of a system to deliver video content;

FIG. **2** is a block diagram of a third particular embodiment of a system to deliver video content;

FIG. **3** is a flow diagram of a particular embodiment of a method of delivering video content;

FIG. **4** is a flow diagram of a second particular embodiment of a method of delivering video content;

FIG. **5** is a flow diagram of a third particular embodiment of a method of delivering video content;

FIG. **6** is a flow diagram of a fourth particular embodiment of a method of delivering video content;

FIG. **7** is a flow diagram of a fifth particular embodiment of a method of delivering video content;

FIG. **8** is a flow diagram of a sixth particular embodiment of a method of delivering video content; and

FIG. **9** is a diagram of an illustrative embodiment of a general computer system.

DETAILED DESCRIPTION OF THE DRAWINGS

A method includes receiving, at a set-top box device, first video content associated with a requested channel from a first source. The method also includes, in response to receiving the first video content, requesting second video content associated with the requested channel from a second source. The method further includes, in response to receiving the second video content from the second source, determining whether at least one data packet associated with the requested channel was not received based on a comparison of first data packets corresponding to the first video content received from the first source and second data packets corresponding to the second video content received from the second source. The method further includes, in response to a determination that at least one data packet was not received, sending a retry request to the first source. The retry request includes an overhead bandwidth factor.

In another embodiment, an apparatus includes processing logic and a memory accessible to the processing logic. The memory includes instructions executable by the processing logic to execute a method. The method includes, receiving, at a set-top box device, first video content associated with a requested channel from a first source. The method also includes, in response to receiving the first video content, requesting second video content associated with the requested channel from a second source. The method further includes, in response to receiving the second video content from the second source, determining whether at least one data packet associated with the requested channel was not received based on a comparison of first data packets corresponding to the first video content received from the first source and second data packets corresponding to the second video content received from the second source. The method further includes, in response to a determination that at least one data packet was not received, sending a retry request to the first source. The retry request includes an overhead bandwidth factor.

In another particular embodiment, a non-transitory computer-readable medium is disclosed having processor-readable instructions that are executable by a processor to execute a method. The method receiving, at a set-top box device, first video content associated with a requested channel from a first source. The method also includes, in response to receiving the first video content, requesting second video content associated with the requested channel from a second source. The method further includes, in response to receiving the second video content from the second source, determining whether at least one data packet associated with the requested channel was not received based on a comparison of first data packets corresponding to the first video content received from the first source and second data packets corresponding to the second video content received from the second source. The method further includes, in response to a determination that at least one data packet was not received, sending a retry request to the first source. The retry request includes an overhead bandwidth factor.

Referring to FIG. **1**, a particular embodiment of a system to deliver video content is illustrated and designated generally **100**. The system **100** includes a home network **102** having a residential gateway **104** communicating with a plurality of set-top box devices **106** that are coupled to a plurality of display devices **108**. The plurality of set-top box devices **106** can communicate with a D-server **118** via an Internet Protocol Television (IPTV) access network **110**. In an illustrative embodiment, the IPTV access network **110** can include a very-high speed digital subscriber line (VDSL) network **110** that includes a digital subscriber line access multiplexer (DSLAM) **112** communicating with the residential gateway **104**.

The D-server **118** can be a dedicated channel change server, dedicated packet recovery server, or a combination thereof. In an illustrative embodiment, the residential gateway **104** can facilitate communication between the plurality of set-top box devices **106** and the IPTV access network **110**. The D-Server **118** can communicate with the IPTV access network **110** via a network router **116**, such as a router of a regional or metropolitan video distribution hub. In addition, one or more video sources, such as the A-server **120**, can communicate with the IPTV access network **110** via a private IP network **114**, such as an IP backbone network or core IP network. The A-server **120** can be located at a video head-end office, such as a national or super video head-end.

The D-Server **118** can buffer video content of a plurality of channels that it receives from the A-Server **120**. Upon receiving a channel change request, the D-server **118** can unicast IP data packets that include video content of a requested channel to the requesting set-top box device **106** at an increased rate equal to the subscribed bandwidth associated with the set-top box device **106**, plus an overhead bandwidth corresponding to the overhead bandwidth factor, until an amount of video content buffered at the D-Server **118** for the requested channel is sent to the set-top box device **106**. After the D-server **118** sends all the buffered data to the set-top box device **106**, the D-server **118** can reduce the rate at which it transmits video content of the requested channel to the set-top box device **106** to the normal bandwidth allotted to the set-top box device **106**. Additionally, the D-server **118** can send an instruction to the set-top box device **106** to send a join request to a multicast video server, such as the A-server **120**, to join a multicast group associated with the requested channel.

In a particular, illustrative embodiment, one of the set-top box devices **106** can receive a channel change request from a viewer of a display device **108** coupled to the set-top box device **106**. In response to the channel change request, the set-top box device **106** can send a channel change data packet to the D-server **118** via the IPTV access network **110**. The channel change data packet can indicate a requested channel and an overhead bandwidth factor (E), which can represent a ratio between overhead bandwidth to be used to send video in response to the channel change request and a nominal bandwidth typically used to send video to the set-top box device **106**. The overhead bandwidth factor E can range, for example, from 0.1 to 1, indicating that video would be sent in response to a channel change request at an increased rate of (1+E) times the nominal bandwidth (e.g., 1.1 to 2 times the nominal bandwidth) until a pre-buffer queue at the set-top box device **106** is filled or the set-top box device **106** joins a multicast group associated with the requested channel.

In one example, the set-top box device **106** may receive high definition (HD) programming at a nominal bandwidth of 10 megabytes per second (Mbps). If the channel is changed, video of the new channel can be streamed to the set-top box device **106** from the D-server **118** at a rate of 11 Mbps, if E=0.1, until a pre-buffer queue is full at the set-top box device **106**.

In another example, the overhead bandwidth factor can be within a range such that a total rate used to send video content to the set-top box device is faster than the set-top box device can decode video content, but not more than a total bandwidth allocated to the viewer's premise (e.g., 25 Mbps). Thus, if the subscribed bandwidth associated with the set-top box device **106** is equal to 2 Mbps, and E=1, the D-server **118** can determine an overhead bandwidth of 2 Mbps corresponding to the set-top box device **106**. Hence, the D-server **118** can send video content of a requested channel to the set-top box device **106** at a rate of twice the subscribed bandwidth, or 4 Mbps, until a buffer at the set-top box device **106** is filled with video content of the requested channel.

After the set-top box device **106** begins receiving video in response to a channel change request, the set-top box device **106** can send a join request, such as an IGMP join request, to the A-server **120**. After the set-top box device **102** begins receiving data packets from the A-server **120** that include video content associated with the requested channel, the set-top box device **106** can send a stop indication to the D-server **118**, and the D-server **118** can stop unicasting video content to the set-top box device **106** in response to the stop indication. In an illustrative, non-limiting embodiment, the set-top box device **106** can determine whether there is a gap between the unicast video content received from the D-server **118** and the multicast video content received from the A-server **120**. If the set-top box device **106** determines that there is such a gap, the set-top box device **106** can send a retry request to the D-server **118** requesting that lost packets be re-sent. The retry request can include an overhead bandwidth factor, which may be equal to or different than the overhead bandwidth factor corresponding to the channel change request. In response to the retry request, the D-server **118** can re-send one or more data packets that include video content of the requested channel to fill the gap. The re-sent data packets can be transmitted at an increased rate corresponding to the overhead bandwidth factor.

While it may be desirable in some cases to set the overhead bandwidth factor E as high as possible, in order to speed the transmission of channel change video or lost packets, setting the overhead bandwidth factor too high can cause the bandwidth of the IPTV access network **110** to be exceeded. This can cause persistent packet loss and video quality degradation. For instance, if two set-top box devices **106** are receiving HD content, the total bandwidth used at the home network (if no additional voice, video or data services are being used) can be 20 Mbps. If E is set to 1 when one of the set-top box devices changes channels, then the traffic becomes 30 Mbps (i.e., 20 Mbps for the set-top box device receiving the new channel, plus 10 Mbps for the other set-top box device). If both set-top box devices change channels, the total traffic can be 40 Mbps with E set to 1. Thus, the traffic can significantly exceed the bandwidth allotted to the home network **102**. Moreover, the total bandwidth may be exceeded at the physical layer of the IPTV access network **110**, causing severe packet loss to other home networks.

As an alternative, E may be set to 0.1 or 0.2 to avoid exceeding the IPTV access network bandwidth. Thus, for both set-top box devices to change channels in HD, the total bandwidth could be as low as 22 Mbps. However, this prolongs the channel change process, in addition to increasing channel change traffic volume. The increased traffic can eventually impact the core network, such as the private IP network **114**, especially if multiple channels are changed or during peak television viewing hours. Additionally, if E is set to 0.1, lost packet recovery can be ten times longer than when E is set to 1.

Consequently, the set-top box device **106**, the D-server **118**, or any combination thereof, are adapted to dynamically determine the overhead bandwidth factor E in response to individual channel change requests and lost packet recovery requests. The overhead bandwidth factor E can be determined by estimating the available bandwidth with respect to

the home network **102** and the IPTV access network **110** and requesting that the D-server **118** allots overhead bandwidth accordingly.

In an illustrative embodiment, the home network **102** can be allotted a maximum total bandwidth to be used for IPTV traffic, BIPTV, when IPTV service is provisioned. The remaining bandwidth, B_{RM} at the home network **102** at any time can be calculated as:

$$B_{RM}=B_{IPTV}-(N_{HD}*B_{HD}+N_{SD}*B_{SD}+B_E),$$

where N_{HD}=number of set-top box devices receiving HD content; B_{HD}=nominal bandwidth used to send HD content to a single set-top box device; N_{SD}=number of set-top box devices receiving standard definition (SD) content; B_{SD}=nominal bandwidth used to send standard definition content to a single set-top box device; and B_E=any overhead bandwidth being used by the home network **102**.

Remaining bandwidth can be updated for the home network **102** at the D-server **118**, at one or more of the set-top box devices **106**, or any combination thereof, in response to state changes at the set-top box devices **106**. Table 1 illustrates types of state changes and corresponding remaining bandwidth updates:

TABLE 1

STB State Changes	B_{RM} Update
Starts a HD channel	$B_{RM} = B_{RM(PREV)} - B_{HD}$
Stops a HD channel	$B_{RM} = B_{RM(PREV)} + B_{HD}$
Change channel from HD to HD	$B_{RM} = B_{RM(PREV)} - E_{LIMIT} * B_{HD}$
Change channel from HD to SD	$B_{RM} = B_{RM(PREV)} + B_{HD} - (1 + E_{LIMIT})* B_{SD}$
Change channel from HD completed	$B_{RM} = B_{RM(PREV)} + E_{LIMIT} * B_{HD}$
HD channel lost packet recovery starts	$B_{RM} = B_{RM(PREV)} - E_{LIMIT} * B_{HD}$
HD channel lost packet recovery completes	$B_{RM} = B_{RM(PREV)} + E_{LIMIT} * B_{HD}$
Start to SD channel	$B_{RM} = B_{RM(PREV)} - B_{SD}$
Stop SD channel	$B_{RM} = B_{RM(PREV)} + B_{SD}$
Change channel from SD to SD	$B_{RM} = B_{RM(PREV)} - E_{LIMIT} * B_{SD}$
Change channel from SD to HD	$B_{RM} = B_{RM(PREV)} + B_{SD} - (1 + E_{LIMIT})* B_{HD}$
Change channel to SD completed	$B_{RM} = B_{RM(PREV)} + E_{LIMIT} * B_{SD}$
SD channel lost packet recovery start	$B_{RM} = B_{RM(PREV)} - E_{LIMIT} * B_{SD}$
SD channel lost packet recovery completes	$B_{RM} = B_{RM(PREV)} + E_{LIMIT} * B_{SD}$

In order to avoid an overhead bandwidth that exceeds limits for the home network **102** and the IPTV access network **110**, an upper limit for the overhead bandwidth factor, or E_{LIMIT}, can be calculated:

$$E_{LIMIT} = \min\left\{1, \frac{\begin{array}{c}B_{RM} + n_{HSD}*(B_{HD} - B_{SD}) + \\ n_{SHD}*(B_{SD} - B_{HD}) - n_{HDa}*B_{HD} - n_{SDa}*B_{SD})\end{array}}{(n_{HD} + n_{SHD} + n_{HDa})*B_{HD} + (n_{SD} + n_{HSD} + n_{SDa})*B_{SD}}\right\}$$

where n_{HD}=a number of set-top box devices requesting HD to HD channel change; n_{HSD}=a number of set-top box devices requesting HD to SD channel change; n_{HDa}=a number of set-top box devices going from start-up to requesting a HD channel; n_{SD}=a number of set-top box devices requesting SD to SD channel change or SD lost packet recovery; n_{SHD}=a number of set-top box devices requesting SD to HD channel change; and n_{SDa}=a number of set-top box devices going from start-up to requesting a SD channel.

In a particular embodiment, the E_{LIMIT} can be restricted not to exceed 1. Additionally, the E_{LIMIT} can be restricted not to fall below 0.1, such that there is sufficient overhead bandwidth for instant channel change or packet recovery. Thus, if the calculated E_{LIMIT} exceeds 1, the E_{LIMIT} used to transmit video or lost packets is 1. Whereas, if the calculated E_{LIMIT} is between 0.1 and 1, the calculated E_{LIMIT} is used, and the remaining bandwidth is updated using the formula

$$B_{RM}+n_{HSD}*(B_{HD}-B_{SD})+n_{SHD}*(B_{SD}-B_{HD})-n_{HDa}*B_{HD}-n_{SDa}*B_{SD})$$

If the calculated E_{LIMIT} is less than 0.1, bandwidth occupied by channels on which there is no subscriber activity for a pre-defined period of time can be used for channel change and packet recovery. Alternatively, the channel change or lost packet recovery request can be denied.

In other embodiments, the upper limit overhead bandwidth factor E_{LIMIT} can be estimated based on a number of active set-top box devices in the home network **102**. For instance, E_{LIMIT} can be allocated based on the number of set-top box devices associated with HD channels (N_{HD}) and the number of set-top box devices associated with SD channels (N_{SD}), where N_{HD} and N_{SD}, take into account channel changes and set-top box start-ups during a synchronization period (T_H). Thus, E_{LIMIT} can be estimated as:

$$E_{LIMIT} = \min\left\{1, \frac{B_{IPTV}}{N_{HD}*B_{HD} + N_{SD}*B_{SD}} - 1\right\}$$

In an illustrative, non-limiting embodiment, a set-top box device or server that provides E_{LIMIT} values can be adapted to store a table of E_{LIMIT} values corresponding to varying values of N_{HD} and N_{SD} such that E_{LIMIT} need not be calculated for every bandwidth change request.

In still other embodiments, E_{LIMIT} values can be estimated by assuming a worst-case traffic scenario based on a number of active set-top box devices and a maximum allowable number of set-top box devices tuned to HD channels. In this embodiment, E_{LIMIT} can be estimated as:

$$E_{LIMIT} = \min\left\{1, \frac{B_{IPTV}}{\begin{array}{c}\min(N_{HD} + N_{SD}, \max N_{HD})*B_{HD} + \\ (N_{HD} + N_{SD} - \min(N_{HD} + N_{SD}, \max N_{HD}))*B_{SD}\end{array}} - 1\right\}$$

Calculation of overhead bandwidth factors and remaining bandwidth for a home network can be performed by one or more set-top box devices **106** in the home network **102**, at a D-server **110**, at another device, or any combination

thereof. In a particular, illustrative embodiment, the set-top box devices **106** within the home network **102** can be adapted to dynamically select a master set-top box device to track remaining bandwidth for the home network **102** and to determine overhead bandwidth factors for all set-top box devices requesting a bandwidth change, such as a channel change or lost packet recovery. For instance, when a set-top box device powers on, it can broadcast a notification that it is active to other set-top box devices of the home network **102** via the residential gateway **104**. If the set-top box device **106** receives no response from other set-top box devices of the home network **102**, the set-top box device can designate itself as a master set-top box device for the home network **102**.

When a state change occurs at the master set-top box device the master set-top box device can update a remaining bandwidth (B_{RM}) related to the home network **102**. If the state change includes an instant channel change request or a lost packet recovery request, the master set-top box device can calculate an overhead bandwidth factor (E_{LIMIT}). The master set-top box device can send its channel change or packet recovery request to the D-Server **118** with the E_{LIMIT} value encapsulated in the request packet. The master set-top box device can receive the channel change packets or lost data packets that it has requested from the D-Server **118**.

The master set-top box device can also receive notifications of state changes from slave set-top box devices within the home network **102**. If the master set-top box device has received a notification of a state change at a slave set-top box device, the master set-top box device can update the remaining bandwidth (B_{RM}) related to the home network. If the state change includes an instant channel change request or a lost packet recovery request, the master set-top box device can calculate an overhead bandwidth factor (E_{LIMIT}) and send the E_{LIMIT} value to the slave set-top box device. The slave set-top box device can send its channel change or packet recovery request to a D-Server **118** with the E_{LIMIT} value encapsulated in the request packet. Alternatively, the master set-top box device can send the request to the D-server **118** on behalf of the slave set-top box device.

In another embodiment, each set-top box device **106** within a home network can independently and redundantly track remaining bandwidth (B_{RM}) related to the home network **102** based on notifications of state changes from the other active set-top box devices. In this embodiment, remaining bandwidth can be updated immediately for stop events and completed events. For other state changes, a set-top box device can start a hold-down time (T_H) to allow state changes at other set-top box devices to initiate, resolve, or synchronize, before calculating remaining bandwidth and, thus, determining necessary an overhead bandwidth factors (E_{LIMIT}).

In a particular embodiment, a configurable lost packet threshold (L_{TH}) can be set to a number of packets that the DSLAM **112** can absorb. If fewer than the threshold number of lost packets are to be recovered, the remaining bandwidth updating process and the E_{LIMIT} calculation process can be skipped. The DSLAM **112** can buffer the retransmitted packets for a short period of time if no bandwidth is available.

The D-server **118** can respond to channel change and lost packet recovery requests by calculating an overhead bandwidth factor (E_{opt}) that represents the overhead bandwidth that the D-server **118** can support based on its central processing unit (CPU) load(s). The D-server **118** can then set the overhead bandwidth factor used to send content to the requesting set-top box device at $E=\min\{E_{opt}, E_{LIMIT}\}$.

In yet another embodiment, the D-server **118** can monitor active set-top box devices within the home network **102**. The D-server **118** can receive a notification of a state change at one of the active set-top box devices and update a remaining bandwidth (B_{RM}) related to the home network **102**. If the state change requires an overhead bandwidth, the D-server **118** can calculate an overhead bandwidth factor (E_{LIMIT}) related to the home network **102**. The D-server **118** can send channel change or recovery packets to the requesting set-top box device using an overhead bandwidth corresponding to the overhead bandwidth factor (E_{LIMIT}). For example, where the overhead bandwidth factor (E_{LIMIT}) is equal to one, the D-server **118** can send packets to the requesting set-top box device at twice the normal rate at which video content or other data is sent to the set-top box device.

Alternatively, as shown in FIG. **1**B, the D-server **118** can be included in a cluster of servers **117** that includes the D-server **118** and an overhead bandwidth factor calculation server (E-calculation server) **119**. The E-calculation server **119** can be a server that is dedicated to calculating overhead bandwidth factors and remaining bandwidth for the home network **102**, or the E-calculation server **119** can be a D-server that calculates overhead bandwidth factors and remaining bandwidths in addition to delivering video content in response to channel change requests, lost packet recovery requests, or a combination thereof. In the embodiment shown in FIG. **1**B, the E-calculation server **119** can gain information regarding individual set-top box devices and home networks (e.g., B_{IPTV}, N_{HD}, N_{SD}, B_E, etc.), via a subscriber management system **115**.

In an illustrative embodiment, when the D-server **118** receives a channel change or lost packet recovery request, the D-server **118** informs the E-calculation server **119** about the application for the overhead bandwidth (e.g., SD to HD channel change, lost packet recovery, etc.) requests an E_{LIMIT} from the E-calculation server **119**. The E-calculation server **119** can follow rules similar to those used by a master set-top box device to calculate E_{LIMIT}, B_{RM}, or any combination thereof. For instance, if $E_{LIMIT}<0.1$, the E-calculation server **119** can return an E_{LIMIT} value of zero, and if $E_{LIMIT}>1$, the E-calculation server **119** can return an E_{LIMIT} value of one. The E-calculation server **119** does not return values to the set-top box devices. Rather, it returns E_{LIMIT} values to the D-server **118** that received the channel change or lost packet request.

In another illustrative embodiment, a set-top box device **106** can send channel change or lost packet requests directly to the E-calculation server **119**. The set-top box device **106** can indicate the bandwidth change type, such as channel change, lost packet recovery, or starting to receive signal from inactive state. If E_{LIMIT} is less than 0.1, the E-calculation server **119** can return an E_{LIMIT} value of zero to the set-top box device **106**, and the set-top box device **106** can retry its request at a randomized time interval. Alternatively, if E_{LIMIT} is greater than or equal to 0.1, the E-calculation server **119** can select a D-server with fewer loads to handle the request from the set-top box device **106**. The E-calculation server **119** can insert an E_{LIMIT} into the set-top box request and send the request to the selected D-server. The selected D-server can notify the E-calculation server **119** once the bandwidth change event is completed, and the E-calculation server **119** can update the remaining bandwidth B_{RM} associated with the home network **102**.

Referring to FIG. **2**, a third particular embodiment of a system to deliver video content is illustrated. The system **200** includes a set-top box device **202** communicating with a D-server **232** via an Internet Protocol Television (IPTV)

access network **230**. The set-top box device **202** can be one of a plurality of set-top box devices of a home network communicating with the IPTV access network **230**. The D-server **232** can be one of a plurality of D-servers within a D-server cluster. At least one multicast video server **248** can also communicate with the IPTV access network **230**.

The set-top box device **202** includes processing logic **204** and memory **206** accessible to the processing logic **204**. The set-top box device **202** can also include a display interface **210** coupled to a display device **212** and a remote interface **214** that communicates with a remote control device **216**. Further, the set-top box device includes a network interface **208** that facilitates communication between the set-top box device **202** and the IPTV access network **230**. In an illustrative embodiment, the network interface **208** can be coupled to a residential gateway device or other home network device and can also facilitate communication between the set-top box device **202** and other set-top box devices of a home network.

The memory **206** includes various modules **218-226** that are adapted to provide functions of the set-top box device **202** with respect to the delivery of video content. In one embodiment, the modules **218-226** can include instructions executable by the processing logic **204**, such as instructions included in one or more applications, operating systems, other software, or any combination thereof, stored at the set-top box device **202**. In other embodiments, the modules **218-226** can include hardware logic or a combination of hardware logic and software instructions.

In a particular embodiment, the memory **206** can include a channel change module **218** that is executable by the processing logic **204** to receive a channel change command from the remote control device **216** and to send a channel change request packet to the D-server **232**. The channel change request packet can include data indicating a requested channel and an overhead bandwidth factor. The channel change module **218** can be executable by the processing logic **204** to send the channel change request packet to the D-server **232** directly from the set-top box device **202** or via a master set-top box device with which the set-top box device **202** communicates. In an illustrative embodiment, the channel change module **218** can be executable by the processing logic **204** to send a stop request to the D-server **232** indicating that the set-top box device **202** has been joined with a multicast group of the requested channel, such that the D-server **232** can stop sending video packets of the requested channel to the set-top box device **202**.

In a particular embodiment, the memory **206** includes a lost packet recovery module **220** that is executable by the processing logic **204** to determine whether a gap exists between video packets received from the D-server **232** in response to a channel change request and video packets received from the multicast video server **248** after the set-top box device **202** has been joined with a multicast group of the requested channel. If such a gap exists, the packet recovery module **220** is executable by the processing logic **204** to send a request for lost video packets to the D-server **232**. The lost packet recovery request can identify lost packets to be re-sent and can include an overhead bandwidth factor.

In a particular embodiment, the memory **206** includes a bandwidth calculation module **222** that is executable by the processing logic **204** to calculate overhead bandwidth factors indicating a percentage or multiple of the normal bandwidth allocated to the set-top box device **202** (or to another set-top box device of a home network), where the overhead bandwidth factors can be used to allocate additional bandwidth to the set-top box device **202** (or to another set-top box device of a home network) for sending video packets in response to channel change, lost packet recovery request, or combinations thereof. In addition, the bandwidth calculation module **222** is executable by the processing logic **204** to calculate and update remaining bandwidth for a home network, based on state changes of the set-top box device **202** and of other set-top box devices of the home network.

In a particular embodiment, the memory **206** includes a slave/master module **224** that is executable by the processing logic **204** to determine whether the set-top box device **202** is to perform functions of a master set-top box device, such as calculating overhead bandwidth factors for itself and other set-top box devices in a home network; tracking state changes of itself and other set-top box devices in the home network and updating a remaining bandwidth value based thereon; communicating bandwidth change requests to the D-server **232** on behalf of itself; communicating bandwidth change requests to the D-server **232** on behalf of other set-top box devices in the home network; or any combination thereof. The slave/master module **224** is also executable by the processing logic **204** to determine whether the set-top box device **202** is to perform functions of a slave set-top box device, such as reporting state changes to a master set-top box device; receiving overhead bandwidth factors from the master set-top box device in response to bandwidth change requests; communicating bandwidth change requests to the D-server **232** on behalf of itself; communicating bandwidth change requests to the master set-top box device for forwarding to the D-server **232**; or any combination thereof.

In a particular embodiment, the memory **206** can include a video content buffer **226** to buffer video content received from the multicast video server **248** and the D-server to prevent underflow to the display device **212**.

The D-server **232** includes processing logic **234** and memory **236** accessible to the processing logic **234**. The D-server **232** also includes a network interface **238** that facilitates communication between the D-server **232** and the IPTV access network **230**. The memory **236** includes various modules **240-244** that are adapted to provide functions of the D-server **232** with respect to the delivery of video content. In one embodiment, the modules **240-244** can include instructions executable by the processing logic **234**, such as instructions included in one or more applications, operating systems, other software, or any combination thereof, stored at the D-server **232**. In other embodiments, the modules **240-244** can include hardware logic or a combination of hardware logic and software instructions.

In a particular embodiment, the memory **236** includes a set-top box communication module **240** that is executable by the processing logic **234** to receive bandwidth change requests from the set-top box device **202**, such as channel change requests, lost packet recovery requests, stop requests, or any combination thereof, and to send video packets to the set-top box device **202** in response to certain bandwidth change requests.

The memory **236** also includes a bandwidth allocation module **242** that is executable by the processing logic **234** to allocate bandwidth to set-top box devices. For example, the bandwidth allocation module **242** can store data indicating normal or allotted bandwidths associated with various set-top box devices and home networks communicating with the IPTV access network **230**. Additionally, the bandwidth allocation module **242** can be executable by the processing logic **234** to allocate additional bandwidth to set-top box devices in response to certain bandwidth change requests and to release such additional bandwidth after state changes associated with such bandwidth change requests are

resolved. The set-top box communication module **240** can be executable by the processing logic **234** to send video packets to the set-top box devices according to the allocated bandwidths.

In a particular embodiment, the memory **236** can include a video content module **244** that is adapted to receive and store video content for communication to set-top box devices. In an illustrative embodiment, the D-server **232** can receive such video content from an A-server, such as the A-server illustrated in FIGS. **1**A-!B, from at least one multicast video server, such as the multicast video server **248**, from other content sources, or any combination thereof.

Referring to FIG. **3**, a particular embodiment of a method of delivering video content is illustrated. At block **300**, a set-top box device powers on. Moving to block **302**, the set-top box device broadcasts a notification that it is active to other set-top box devices of a home network, via a residential gateway, for example. Proceeding to block **304**, in a particular embodiment, the set-top box device can receive a response from a master set-top box device of the home network, such as a set-top box device that was powered on before all other active set-top box devices in the home network.

Continuing to decision node **306**, the set-top box device can determine whether a state change has occurred at the set-top box device. If a state change has not occurred, the method can advance to decision node **322**. Conversely, if a state change has occurred, the method can move to block **308**, and the set-top box device informs the master set-top box device of the state change. Proceeding to decision node **310**, if the state change includes an instant channel change request or a lost packet recovery request, the method can advance to block **312**, and the set-top box device can receive a calculated overhead bandwidth factor (E_{LIMIT}) from the master set-top box device.

At decision node **314**, the set-top box device can determine whether the returned E_{LIMIT} value is equal to zero. If the E_{LIMIT} value is equal to zero, the value can indicate a denial of the channel change/packet recovery request sent by the set-top box device, due to a lack of available overhead bandwidth. The method can move to decision node **316**, and the set-top box device can determine whether to retry the request at another time, such as after a randomized delay time has expired or after receiving a notification that another set-top box device has powered off or has completed a channel change or packet recovery process.

Returning to decision node **314**, if the E_{LIMIT} value is not equal to zero, the set-top box device can send its channel change or packet recovery request to a D-Server with the E_{LIMIT} value encapsulated in the request packet. Proceeding to block **320**, the set-top box device can receive the channel change packets or lost data packets that it has requested from the D-Server. Moving to decision node **322**, in one embodiment, the set-top box device can determine whether it has received a command to power off. If it has not received such a command, the method can return to decision node **306**. On the other hand, if the set-top box device has received a command to power off, the method can advance to block **324**, and the set-top box device can inform the master set-top box device that it is powering off. The method then terminates at **326**.

Referring to FIG. **4**, a second particular embodiment of a method of delivering video content is illustrated. At block **400**, a set-top box device powers on. Moving to block **402**, the set-top box device broadcasts a notification that it is active to other set-top box devices of a home network, via a residential gateway, for example. Proceeding to block **404**, in a particular embodiment, the set-top box device receives no response from other set-top box devices of the home network, and the set-top box device designates itself as a master set-top box device for the home network.

Continuing to decision node **406**, the master set-top box device can determine whether a state change has occurred at the master set-top box device. If a state change has occurred at the master set-top box device, the method can move to block **408**, and the master set-top box device can update a remaining bandwidth (B_{RM}) related to the home network. Proceeding to decision node **410**, if the state change includes an instant channel change request or a lost packet recovery request, the method can advance to block **412**, and the master set-top box device can calculate an overhead bandwidth factor (E_{LIMIT}). Moving to block **414**, the master set-top box device can send its channel change or packet recovery request to a D-Server with the E_{LIMIT} value encapsulated in the request packet. Proceeding to block **415**, the master set-top box device can receive the channel change packets or lost data packets that it has requested from the D-Server.

Returning to decision node **406**, if a state change has not occurred at the master set-top box device, the method can proceed to decision node **416**, and the master set-top box device can determine whether it has received a notification of a state change from a slave set-top box device, such as a set-top box device within the home network that became active after the master set-top box device became active. If the master set-top box device has received a notification of a state change at a slave set-top box device, the method can move to block **418**, and the master set-top box device can update the remaining bandwidth (B_{RM}) related to the home network. Proceeding to decision node **420**, if the state change includes an instant channel change request or a lost packet recovery request, the method can advance to block **422**, and the master set-top box device can calculate an overhead bandwidth factor (E_{LIMIT}) and send the E_{LIMIT} value to the slave set-top box device. Moving to block **414**, the master set-top box device can send its channel change or packet recovery request to a D-Server with the E_{LIMIT} value encapsulated in the request packet.

At decision node **424**, in one embodiment, and the master set-top box device can determine whether it has received a command to power off. If it has not received such a command, the method can return to decision node **406**. On the other hand, if the set-top box device has received a command to power off, the method can advance to block **426**, and the set-top box device can inform the master set-top box device that it is powering off. The method then terminates at **428**.

Referring to FIG. **5**, a third particular embodiment of a method of delivering video content is illustrated. At block **500**, a set-top box device powers on. Moving to block **502**, the set-top box device broadcasts a notification that it is active to other active set-top box devices of a home network. Proceeding to block **504**, in a particular embodiment, the set-top box device tracks state changes of the other active set-top box devices and maintains an updated remaining bandwidth (B_{RM}) related to the home network based on notifications of state changes from the other active set-top box devices.

Continuing to decision node **506**, the set-top box device can determine whether a state change has occurred at the set-top box device. If a state change has occurred at the master set-top box device, the method can move to block **508**, and the set-top box device can inform the other active set-top box devices of the state change, such that each active

set-top box device can independently maintain an updated remaining bandwidth (B_{RM}) related to the home network. Advancing to decision node **510**, if the state change requires overhead bandwidth, such as an instant channel change request or a lost packet recovery request, the method can advance to block **512**, and the set-top box device can start a hold-down time (T_H). At block **514**, the hold-down time can expire, and the set-top box device can calculate an overhead bandwidth factor (E_{LIMIT}), at block **516**, to include with a channel change or lost packet recovery request to a D-Server communicating with the home network.

Moving to decision node **518**, the set-top box device can determine whether the overhead bandwidth factor (E_{LIMIT}) is greater than or equal to a pre-defined minimum overhead bandwidth factor (E_{min}). If the overhead bandwidth factor (E_{LIMIT}) is not greater than or equal to a pre-defined minimum overhead bandwidth factor (E_{min}), the method can return to **512**, and the set-top box device can postpone its request to the D-Server until the overhead bandwidth factor (E_{LIMIT}) is greater than or equal to the pre-defined minimum overhead bandwidth factor (E_{min}). When the overhead bandwidth factor (E_{LIMIT}) is greater than or equal to a pre-defined minimum overhead bandwidth factor (E_{min}), the set-top box device can send its channel change or lost packet recovery request to the D-Server, at block **522**. The set-top box device can receive channel change or recovery packets at block **524**.

Proceeding to block **526**, in a particular embodiment, the set-top box device can inform other active set-top box devices within the home network that the overhead bandwidth used for its channel change or packet recovery process has been released. In an illustrative embodiment, the method can include decision node **528**, at which the set-top box device can determine whether it has received a command to power off. If it has not received such a command, the method can return to block **504**. On the other hand, if the set-top box device has received a command to power off, the method can terminate at **530**.

Referring to FIG. **6**, a fourth particular embodiment of a method of delivering video content is illustrated. At block **602**, a master set-top box device within a home network monitors for bandwidth change requests from other set-top box devices within the home network. Moving to block **604**, the master set-top box device receives a bandwidth change request from another set-top box device. Proceeding to decision step **606**, the master set-top box device determines whether the bandwidth change request is a stop request, such as a notification that a set-top box device is powering off. If the master set-top box device determines that the bandwidth change request is not a stop request, the method advances to block **608**, and the master set-top box device updates a remaining bandwidth (B_{RM}) associated with the home network. Conversely, if the master set-top box device determines that the bandwidth change request is not a stop request, the method advances to decision node **610**, and the master set-top box device determines whether the bandwidth change request is a lost packet recovery request. If the bandwidth change request is not a lost packet recovery request (e.g., if the request is a channel change request), the method advances to block **616**. On the other hand, if the bandwidth change request is a lost packet recovery request, the method continues to decision node **612**.

At decision node **612**, the master set-top box device determines whether a lost packet count related to the lost packet recovery request is less than a lost packet count threshold (L_{TH}). If the master set-top box device determines that the lost packet count is less than the lost packet count threshold, the method moves to block **614**, and the master set-top box device can send the lost packet recovery request to a D-server with a maximum overhead bandwidth factor (E_{LIMIT}) equal to one, such that the D-server can send the lost packets to the requesting set-top box device (e.g., via the home network) at twice the normal bandwidth. The method can then return to block **602**.

Returning to decision node **612**, if the master set-top box device determines that the lost packet count is greater than or equal to the lost packet count threshold, the method advances to block **616**, and the master set-top box device can reset and restart a hold-down timer (T_H) and can add the requesting set-top box device to a count of set-top box devices needing overhead bandwidth. Moving to block **618**, the hold-down timer expires. Proceeding to block **620**, the master set-top box device stops counting the requesting set-top box device, calculates a maximum overhead bandwidth factor for the requesting set-top box device, and resets the count of set-top box devices.

Continuing to decision node **622**, the master set-top box device determines whether the calculated maximum overhead bandwidth factor is greater than one. If the calculated maximum overhead bandwidth factor is greater than one, the method advances to block **624**, and the master set-top box device allocates the maximum overhead bandwidth factor to one. The method can then return to **608**. On the other hand, if the master set-top box device determines that the calculated maximum overhead bandwidth factor is not greater than one, the method moves to decision node **626**, and the master set-top box determines whether the calculated maximum overhead bandwidth factor is less than a minimum overhead bandwidth (E_{min}).

If the set-top box determines that the calculated maximum overhead bandwidth factor is not less than the minimum overhead bandwidth, the method proceeds to block **628**, and the master set-top box device allocated the maximum overhead bandwidth factor to the calculated value. The method can then return to block **608**. Conversely, if the set-top box determines that the calculated maximum overhead bandwidth factor is less than the minimum overhead bandwidth, the method continues to block **630**, and the master set-top box device allocates the maximum overhead bandwidth value to zero. The method can then return to **602**.

Referring to FIG. **7**, a fifth particular embodiment of a method of delivering video content is illustrated. At block **700**, a D-Server monitors active set-top box devices communicating with an Internet Protocol Television (IPTV) access network. Moving to decision node **702**, the D-Server can determine whether it has received a notification of a state change at one of the active set-top box devices. If the D-Server receives such a notification, the method proceeds to block **704**, and the D-Server updates a remaining bandwidth (B_{RM}) related to a household or home network associated with the set-top box device.

Continuing to decision node **706**, the D-Server can determine whether the state change includes a request that requires an overhead bandwidth, such as an instant channel change request or lost packet recovery request. If the state change does not require an overhead bandwidth, the method can return to block **700**. Conversely, if the state change requires an overhead bandwidth, the method advances to block **708**, and the D-Server calculates an overhead bandwidth factor (E_{LIMIT}) related to the household. Moving to block **710**, the D-Server sends channel change or recovery packets to the requesting set-top box device using an overhead bandwidth corresponding to the overhead bandwidth factor (E_{LIMIT}). For example, where the overhead bandwidth

factor (E_{LIMIT}) is equal to one, the D-Server can send packets to the requesting set-top box device at twice the normal rate. The method can return to block **700**.

Referring to FIG. **8**, a sixth particular embodiment of a method of delivering video content is illustrated. At block **800**, an E-calculation server that is part of a cluster of D-servers monitors active set-top box devices. In an illustrative embodiment, the E-calculation server can monitor bandwidth usage of such set-top box devices via a subscriber management system. Moving to decision node **802**, the E-calculation server can determine whether it has detected or been informed of a state change at an active set-top box device. If so, the method proceeds to block **804**, and the E-calculation server updates a remaining bandwidth value (B_{RM}) associated with a home network of the set-top box device.

Continuing to decision node **806**, the E-calculation server can determine whether it has received a bandwidth change request. The bandwidth change request can include, for example, a channel change request, a lost packet recovery request, or a start-up request. Such a request can be received directly from a set-top box device or from a D-server to which the request was sent by the set-top box device. If the E-calculation server receives a bandwidth change request, the method advances to block **808**, and the E-calculation server calculate or estimates an overhead bandwidth factor (E_{LIMIT}) to be used in responding to the bandwidth change request.

At decision node **810**, the E-calculation server can determine whether the calculated or estimated overhead bandwidth factor is less than a minimum threshold, such as 0.1. If so, the method moves to block **812**, and the E-calculation server can send a denial to the set-top box device or D-server. The requesting set-top box device can retry its request after a delay period. Whereas, if the E-calculation server determines that the calculated or estimated overhead bandwidth factor is greater than or equal to the minimum threshold, the method moves to bock **814**, and the E-calculation server can select a D-server to handle the bandwidth change request based on load across a plurality of D-servers. Proceeding to block **816**, the E-calculation server sends the set-top box request with the E_{LIMIT} value to the selected D-server.

In a particular embodiment, the E-calculation server can receive a notification from the selected D-server when the bandwidth change event is completed. The method can then advance to block **820**, and the E-calculation server can update the remaining bandwidth for the home network to reflect the release of the overhead bandwidth used to response to the bandwidth change request.

Referring to FIG. **9**, an illustrative embodiment of a general computer system is shown and is designated **900**. The computer system **900** can include a set of instructions that can be executed to cause the computer system **900** to perform any one or more of the methods or computer based functions disclosed herein. The computer system **900** may operate as a standalone device or may be connected, e.g., using a network, to other computer systems or peripheral devices.

In a networked deployment, the computer system may operate in the capacity of a server or as a client user computer in a server-client user network environment, or as a peer computer system in a peer-to-peer (or distributed) network environment. The computer system **900** can also be implemented as or incorporated into various devices, such as a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile device, a palmtop computer, a laptop computer, a desktop computer, a communications device, a wireless telephone, a land-line telephone, a control system, a camera, a scanner, a facsimile machine, a printer, a pager, a personal trusted device, a web appliance, a network router, switch or bridge, or any other machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. In a particular embodiment, the computer system **900** can be implemented using electronic devices that provide voice, video or data communication. Further, while a single computer system **900** is illustrated, the term "system" shall also be taken to include any collection of systems or sub-systems that individually or jointly execute a set, or multiple sets, of instructions to perform one or more computer functions.

As illustrated in FIG. **9**, the computer system **900** may include a processor **902**, e.g., a central processing unit (CPU), a graphics processing unit (GPU), or both. Moreover, the computer system **900** can include a main memory **904** and a static memory **906**, which can communicate with each other via a bus **908**. As shown, the computer system **900** may further include a video display unit **910**, such as a liquid crystal display (LCD), an organic light emitting diode (OLED), a flat panel display, a solid state display, or a cathode ray tube (CRT). Additionally, the computer system **900** may include an input device **912**, such as a keyboard, and a cursor control device **914**, such as a mouse. The computer system **900** can also include a disk drive unit **916**, a signal generation device **918**, such as a speaker or remote control, and a network interface device **920**.

In a particular embodiment, as depicted in FIG. **9**, the disk drive unit **916** may include a computer-readable medium **922** in which one or more sets of instructions **924**, e.g. software, can be embedded. Further, the instructions **924** may embody one or more of the methods or logic as described herein. In a particular embodiment, the instructions **924** may reside completely, or at least partially, within the main memory **904**, the static memory **906**, and/or within the processor **902** during execution by the computer system **900**. The main memory **904** and the processor **902** also may include computer-readable media.

In an alternative embodiment, dedicated hardware implementations, such as application specific integrated circuits, programmable logic arrays and other hardware devices, can be constructed to implement one or more of the methods described herein. Applications that may include the apparatus and systems of various embodiments can broadly include a variety of electronic and computer systems. One or more embodiments described herein may implement functions using two or more specific interconnected hardware modules or devices with related control and data signals that can be communicated between and through the modules, or as portions of an application-specific integrated circuit. Accordingly, the present system encompasses software, firmware, and hardware implementations.

In accordance with various embodiments of the present disclosure, the methods described herein may be implemented by software programs executable by a computer system. Further, in an exemplary, non-limited embodiment, implementations can include distributed processing, component/object distributed processing, and parallel processing. Alternatively, virtual computer system processing can be constructed to implement one or more of the methods or functionality as described herein.

The present disclosure contemplates a computer-readable medium that includes instructions **924** or receives and executes instructions **924** responsive to a propagated signal,

so that a device connected to a network **926** can communicate voice, video or data over the network **926**. Further, the instructions **924** may be transmitted or received over the network **926** via the network interface device **920**.

While the computer-readable medium is shown to be a single medium, the term "computer-readable medium" includes a single medium or multiple media, such as a centralized or distributed database, and/or associated caches and servers that store one or more sets of instructions. The term "computer-readable medium" shall also include any medium that is capable of storing a set of instructions for execution by a processor or that cause a computer system to perform any one or more of the methods or operations disclosed herein.

In a particular non-limiting, exemplary embodiment, the computer-readable medium can include a solid-state memory such as a memory card or other package that houses one or more non-volatile read-only memories. Further, the computer-readable medium can be a random access memory or other volatile re-writable memory. Additionally, the computer-readable medium can include a magneto-optical or optical medium, such as a disk or tapes. Accordingly, the disclosure is considered to include any one or more of a computer-readable medium or a distribution medium and other equivalents and successor media, in which data or instructions may be stored.

Although the present specification describes components and functions that may be implemented in particular embodiments with reference to particular standards and protocols, the disclosed embodiments are not limited to such standards and protocols. For example, standards for Internet and other packet switched network transmission (e.g., TCP/IP, UDP/IP, HTML, HTTP) represent examples of the state of the art. Such standards are periodically superseded by faster or more efficient equivalents having essentially the same functions. Accordingly, replacement standards and protocols having the same or similar functions as those disclosed herein are considered equivalents thereof.

The illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments. The illustrations are not intended to serve as a complete description of all of the elements and features of apparatus and systems that utilize the structures or methods described herein. Many other embodiments may be apparent to those of skill in the art upon reviewing the disclosure. Other embodiments may be utilized and derived from the disclosure, such that structural and logical substitutions and changes may be made without departing from the scope of the disclosure. Additionally, the illustrations are merely representational and may not be drawn to scale. Certain proportions within the illustrations may be exaggerated, while other proportions may be reduced. Accordingly, the disclosure and the figures are to be regarded as illustrative rather than restrictive.

One or more embodiments of the disclosure may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any particular invention or inventive concept. Moreover, although specific embodiments have been illustrated and described herein, it should be appreciated that any subsequent arrangement designed to achieve the same or similar purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all subsequent adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the description.

The Abstract of the Disclosure is provided with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, various features may be grouped together or described in a single embodiment for the purpose of streamlining the disclosure. This disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter may be directed to less than all of the features of any of the disclosed embodiments. Thus, the following claims are incorporated into the Detailed Description, with each claim standing on its own as defining separately claimed subject matter.

The above-disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other embodiments that fall within the true spirit and scope of the present invention. Thus, to the maximum extent allowed by law, the scope of the present invention is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description.

What is claimed is:

1. A method comprising:

receiving a retry request from a media device at a server, the retry request requesting a data packet associated with video content and including an overhead bandwidth factor corresponding to a ratio between an overhead bandwidth to be used to send the data packet in response to the retry request and a nominal bandwidth used to send other packets to the media device; and

in response to the retry request, sending the data packet to the media device based on the overhead bandwidth factor.

2. The method of claim **1**, wherein the overhead bandwidth factor is based on a count of data packets of the video content not received by the media device.

3. The method of claim **2**, wherein the overhead bandwidth factor has a first value when the count is less than a threshold, and wherein the overhead bandwidth factor has a second value when the count is greater than or equal to the threshold.

4. The method of claim **1**, wherein the data packet is sent via unicast.

5. The method of claim **1**, wherein the data packet includes data associated with a high definition video channel or a standard definition video channel.

6. The method of claim **1**, further comprising sending a plurality of data packets associated with the video content to the media device before receiving the retry request.

7. The method of claim **6**, further comprising:

receiving a stop request prior to receiving the retry request; and

in response to the stop request, ceasing transmission to the media device of packets associated with the video content.

8. The method of claim **6**, wherein the plurality of data packets are sent using a first bandwidth, the data packet is sent using a second bandwidth, and wherein the first bandwidth is not equal to the second bandwidth.

9. The method of claim 6, further comprising reducing a bandwidth used to send additional data packets associated with the video content to the media device after sending the plurality of data packets.

10. The method of claim 6, further comprising sending an instruction to the media device instructing the media device to request additional data packets associated with the video content from a second server.

11. The method of claim 10, wherein the second server is a multicast video server.

12. The method of claim 10, wherein the data packet corresponds to a packet of the video content that was not received by the media device from the server or from the second server.

13. An apparatus comprising:

a processor; and

a memory storing instructions executable by the processor to perform operations including:

receiving a retry request from a media device at a server, the retry request requesting a data packet associated with video content and including an overhead bandwidth factor corresponding to a ratio between an overhead bandwidth to be used to send the data packet in response to the retry request and a nominal bandwidth used to send other packets to the media device; and

in response to the retry request, sending the data packet to the media device based on the overhead bandwidth factor.

14. The apparatus of claim 13, wherein the server is a dedicated channel change server.

15. The apparatus of claim 13, wherein the data packet corresponds to a gap in packets received by the media device, the packets associated with the video content.

16. The apparatus of claim 13, wherein the retry request is received subsequent to a channel change request requesting a channel associated with the video content.

17. A computer-readable storage device comprising processor-executable instructions that, when executed by a processor, cause the processor to:

receive a retry request from a media device at a server, the retry request requesting a data packet associated with video content and including an overhead bandwidth factor corresponding to a ratio between an overhead bandwidth to be used to send the data packet in response to the retry request and a nominal bandwidth used to send other packets to the media device; and

in response to the retry request, send the data packet to the media device based on the overhead bandwidth factor.

18. The computer-readable storage device of claim 17, wherein the overhead bandwidth factor is based on a count of data packets of the video content not received by the media device.

19. The computer-readable storage device of claim 18, wherein the overhead bandwidth factor has a first value when the count is less than a threshold, and wherein the overhead bandwidth factor has a second value when the count is greater than or equal to the threshold.

20. The computer-readable storage device of claim 17, wherein the instructions further cause the processor to send a plurality of data packets associated with the video content to the media device before receiving the retry request.

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